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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

PERFORMANCE OF J33-A-23 TURBOJET-ENGINE COMPRESSOR

I - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR WITH 17-BLADE IMPELLER

By William L. Beede and Harry Kottas

Flight Propulsion Research Laboratory
Cleveland, Ohio

To
By authority J W Crowley per NACA Release Form #2082 Date 12/14/53 exp. of 10581 Bmk 1-13-54

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I - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR WITH 17-BLADE IMPELLER

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SUMMARY

The production-model J33-A-23 turbojet-engine compressor with a 17-blade impeller was operated at ambient and 0° F inlet temperatures and at inlet pressures of 14 and 5 inches mercury absolute for equivalent impeller speeds from 6000 to 12,750 rpm. The results of this investigation are compared with those of the J33-A-21 compressor.

At the design equivalent speed of 11,750 rpm the maximum pressure ratio was 4.39. This occurred at the surge point at which the equivalent weight flow was 80.8 pounds per second, and the adiabatic temperature-rise efficiency was 0.757. The maximum flow at the design equivalent speed was 88.0 pounds per second. The maximum adiabatic temperature-rise efficiency of 0.799 was obtained at an equivalent speed of 10,000 rpm, and equivalent weight flow of 62.9 pounds per second, and a pressure ratio of 3.20. At the maximum equivalent speed investigated (12,750 rpm), a peak pressure ratio of 4.90 was attained at an equivalent weight flow of 85.4 pounds per second and an efficiency of 0.680.

INTRODUCTION

At the request of the Air Materiel Command, U. S. Air Force, an investigation is being conducted at the NACA Cleveland laboratory to determine the performance characteristics of a series of J33 turbojet-engine compressors. Compressor performance augmentation, such as that

[redacted]

offered by water injection (reference 1) is also being investigated. The over-all performance of the J33-A-21 compressor was reported in reference 2. The present investigation was made of a production-model J33-A-23 compressor with a 17-blade impeller. Runs were made over a range of equivalent impeller speeds from 6000 to 11,750 rpm with an inlet pressure of 14 inches mercury absolute and ambient inlet temperature. Additional runs at the design equivalent speed (11,750) were made at an inlet pressure of 5.0 inches mercury absolute, and inlet temperatures of ambient and 0° F to determine the effect of inlet pressure and temperature on compressor performance. A run was also made at an inlet pressure of 5.0 inches mercury absolute, an inlet temperature of 0° F, and the highest equivalent impeller speed permissible (12,750 rpm), the actual rotor speed being limited by the emergency rating of 12,000 rpm.

APPARATUS AND METHODS

The apparatus and instrumentation are the same as those described in reference 2 with the exception that this impeller has 17 blades per side and the diffuser inlet-vane diameter is 33.76 inches.

The precision of the measurements is estimated to be within the following limits:

Temperature, °F	±0.5
Pressure, inches mercury absolute	±0.04
Air weight flow, percent	±1.0
Speed, percent	±0.3

The over-all performance characteristics of the compressor were determined for the following series of operating conditions:

Equivalent impeller speed, $N/\sqrt{\theta}$ (rpm)	Equivalent tip speed $U/\sqrt{\theta}$ (ft/sec)	Inlet pressure (in. Hg abs.)	Inlet temperature[1] (°F)	Determine effect of
6,000	786	14.0	Ambient	
7,000	916	14.0	Ambient	
8,500	1113	14.0	Ambient	
9,000	1178	14.0	Ambient	Speed
10,000	1309	14.0	Ambient	
11,000	1440	14.0	Ambient	
11,750	1538	14.0	Ambient	
11,750	1538	5.0	Ambient	Inlet pressure
11,750	1538	5.0	0	Inlet temperature
12,750	1669	5.0	0	Speed

[1]Ambient temperature varied from 77° to 92° F.

RESULTS AND DISCUSSION

Effect of speed. - Figures 1 and 2 give an over-all picture of the performance characteristics of the J33-A-23 compressor. At the design equivalent speed of 11,750 rpm the operating limits of the compressor lie between the surge point (80.8 pounds per second) at which the maximum pressure ratio of 4.39 and the maximum adiabatic temperature-rise efficiency of 0.757 occur and the choke flow of 88.0 pounds per second. The maximum adiabatic temperature-rise efficiency of 0.799 was obtained at an equivalent speed of 10,000 rpm, an equivalent weight flow of 62.9 pounds per second, and a pressure ratio of 3.20.

The performance of the compressor at the maximum permissible speed at available inlet conditions in this installation (12,750 rpm) is shown in figure 3. A peak pressure ratio of 4.90 was obtained at the surge point at which the equivalent weight flow was 85.4 pounds per second and the adiabatic temperature-rise efficiency was 0.680. This efficiency is 0.077 lower than that obtained at the peak pressure ratio at the design speed and indicates a critical flow condition between 11,750 and 12,750 rpm. The maximum equivalent weight flow for this speed was 92.5 pounds per second.

Effect of inlet temperature and pressure. - A decrease in inlet temperature from ambient to 0° F caused a slight decrease in peak adiabatic temperature-rise efficiency (fig. 4) and a constant increase of approximately 1 percent in pressure ratio but the effect on weight flow was within the experimental error of the metering device. A decrease in inlet pressure from 14 to 5 inches mercury absolute caused a decrease of approximately 2.7 percent in the peak adiabatic temperature-rise efficiency (fig. 5), a decrease of approximately 3.7 percent in the peak pressure ratio, and a decrease of approximately 2.3 percent in equivalent weight flow. These variations show that there is a Reynolds number effect but data are insufficient to establish this effect quantitatively.

Comparison of performance of J33-A-21 and J33-A-23 compressors. - A comparison of the performance of the J33-A-21 and the J33-A-23 compressors is shown in figure 6. Because the design speeds are different for the two compressors, this comparison is made not only at design speed but also at an equivalent speed of 11,000 rpm, which is the highest speed common to both tests. Representative results are given in the following table:

Equivalent speed, rpm	Peak η_{ad}		$W\sqrt{\theta}/\delta$ at peak η_{ad}		Peak P_2/P_1		$W\sqrt{\theta}/\delta$ at peak P_2/P_1		Maximum $W\sqrt{\theta}/\delta$	
	A-21	A-23	A-21	A-23	A-21	A-23	A-21	A-23	A-21	A-23
Design	0.701	0.757	73.4	80.8	3.98	4.39	73.4	80.8	84.0	88.0
11,000	0.706	0.773	68.7	71.5	3.64	3.87	68.7	71.5	79.5	80.5

The A-23 showed an improvement in all performance characteristics as compared with the A-21.

SUMMARY OF RESULTS

1. At the design equivalent speed of 11,750 rpm the compressor had a maximum pressure ratio of 4.39 at an equivalent weight flow of 80.8 pounds per second and an adiabatic temperature-rise efficiency of 0.757. The maximum equivalent weight flow for this speed was 88.0 pounds per second.

2. A maximum adiabatic temperature-rise efficiency of 0.799 was obtained at an equivalent speed of 10,000 rpm, an equivalent weight flow of 62.9 pounds per second at a pressure ratio of 3.20.

3. At the maximum equivalent speed of 12,750 rpm, a peak pressure ratio of 4.90 was obtained at an equivalent weight flow of 85.4 pounds per second and an adiabatic temperature-rise efficiency of 0.680. The maximum equivalent weight flow at this speed was 92.5 pounds per second.

4. The variation of performance characteristics with inlet pressure and temperature indicates that there is a Reynolds number effect but insufficient data are available to examine this effect in detail.

Flight Propulsion Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, June 15, 1948.

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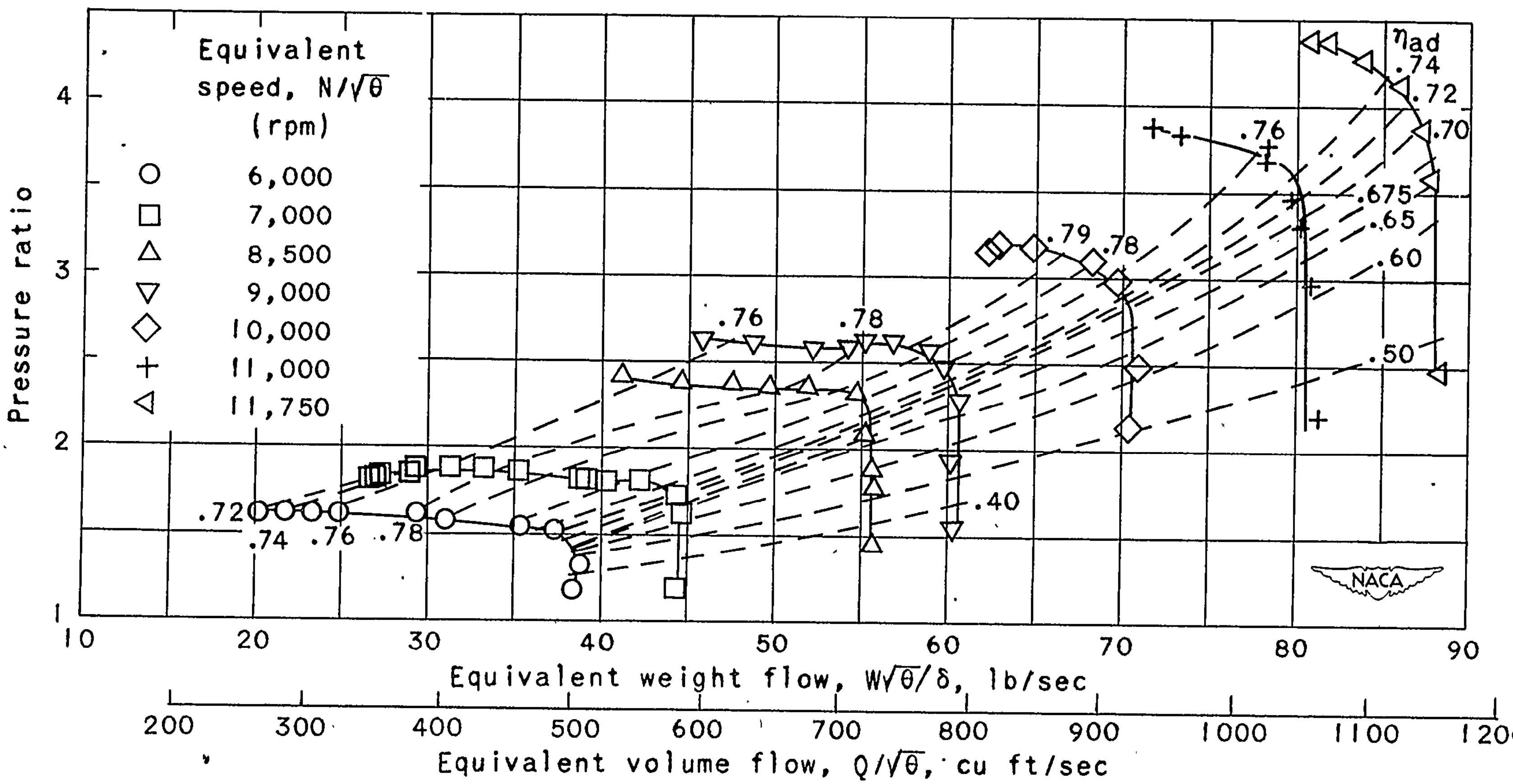


Figure 1. - Variation of pressure ratio with equivalent weight flow at inlet pressure of 14 inches mercury absolute and ambient inlet temperature.

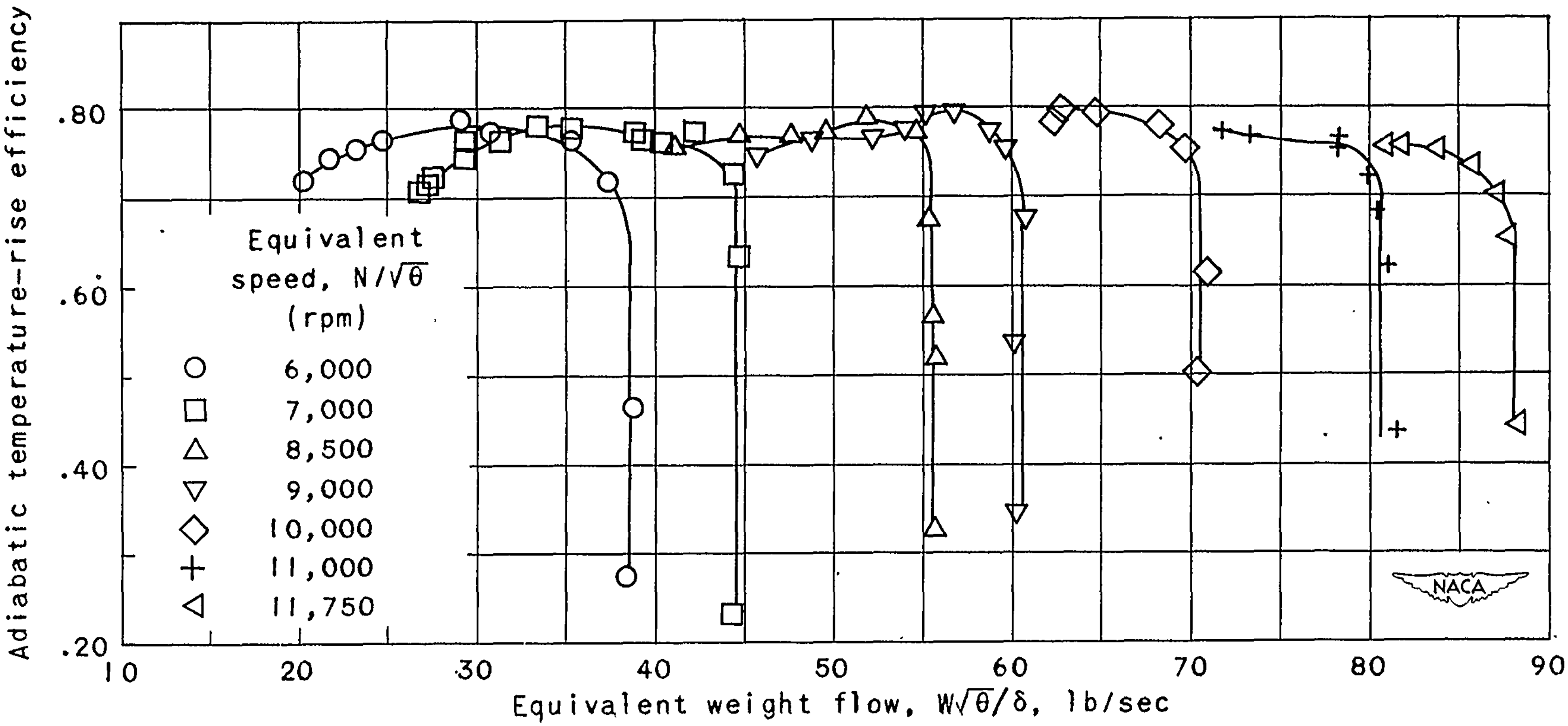


Figure 2. - Variation of adiabatic temperature-rise efficiency with equivalent weight flow at inlet pressure of 14 inches mercury absolute and ambient inlet temperature.

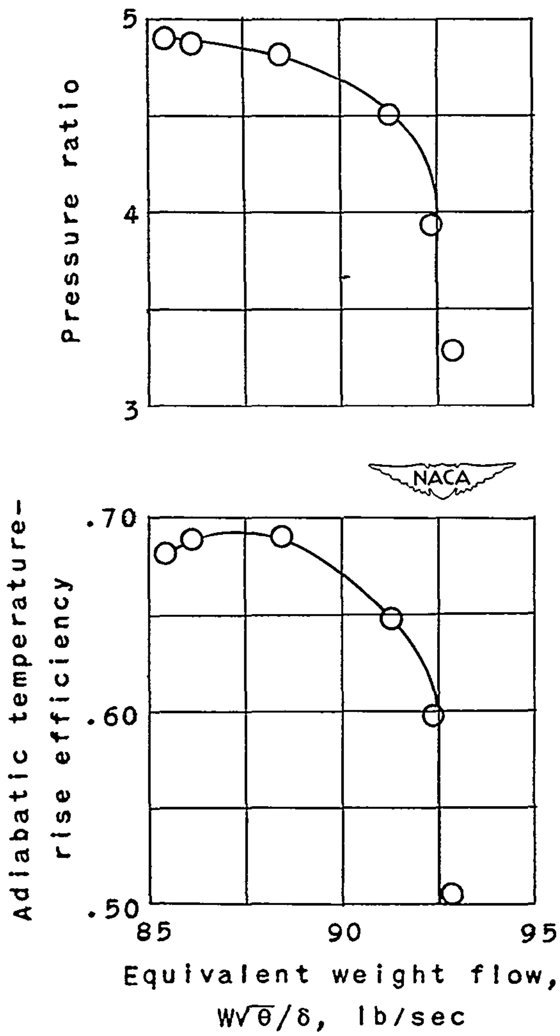


Figure 3. - Performance of compressor at maximum permissible speed of 12,750 rpm. Inlet pressure, 5.0 inches mercury absolute; inlet temperature, 0° F.

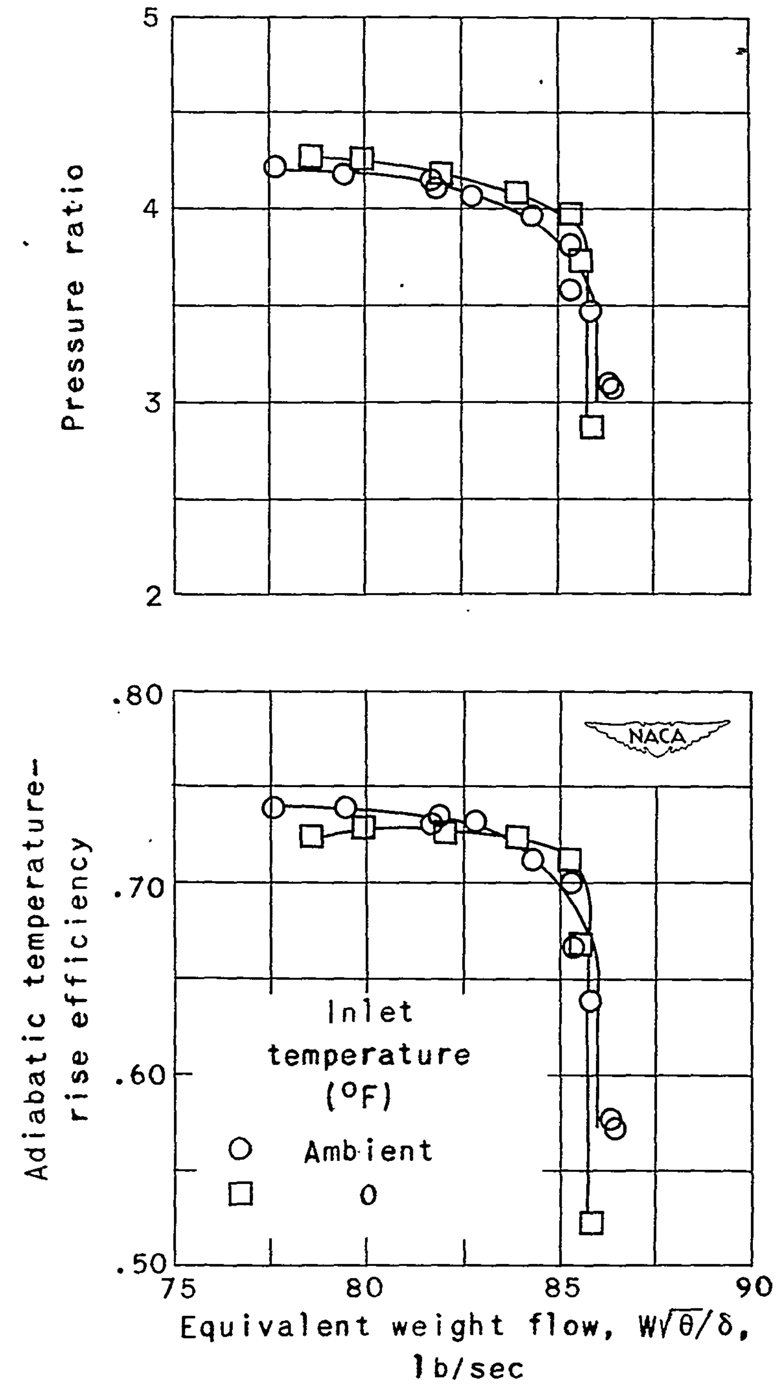


Figure 4. - Effect of inlet temperature on performance at inlet pressure of 5.0 inches mercury absolute and equivalent design speed of 11,750 rpm.

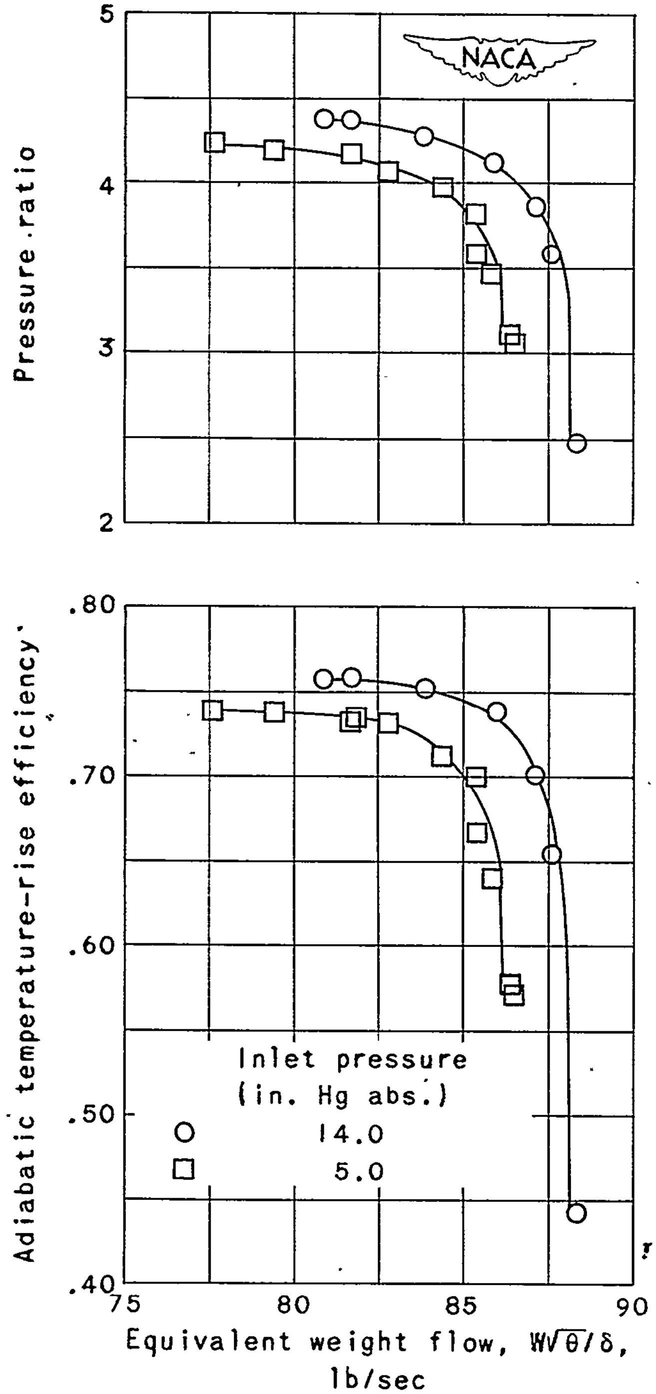
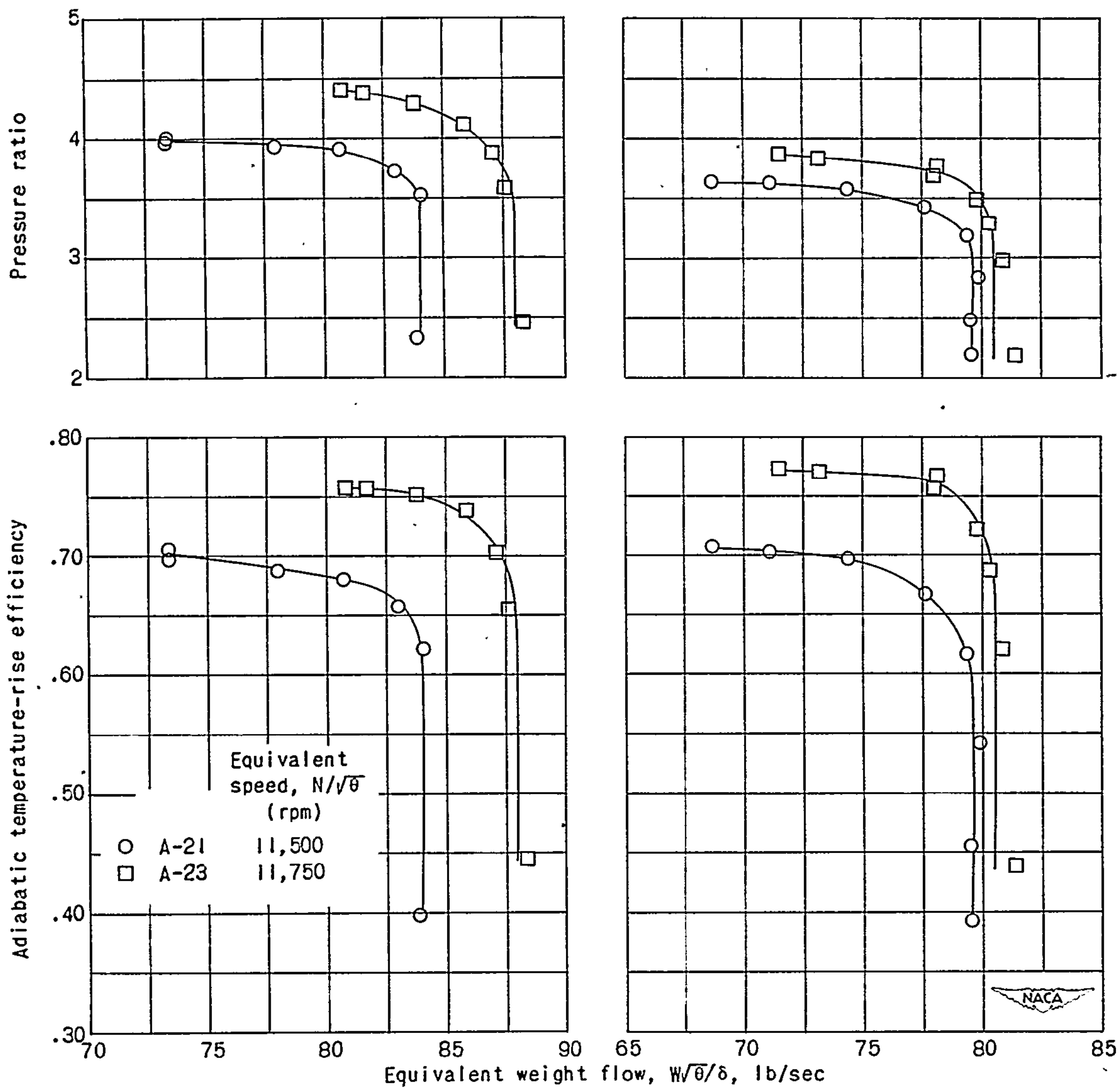


Figure 5. - Effect of inlet pressure on performance at ambient inlet temperature and equivalent design speed of 11,750 rpm.



(a) Design speed. (b) Equivalent speed, 11,000 rpm.

Figure 6. - Comparison of performance of J33-A-21 and J33-A-23 compressors at design speed and highest speed common to both.